Proceedings of a Workshop
The Use of Remote Sensing Technologies & GIS Databases in CGIAR Centers
March 14-17, 1995
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United States Agency for International Development
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CONTENTS

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Executive Summary

The Workshop on Use of Remote Sensing Technologies & Geographic Information Systems (GIS) Databases was held March 14-17, 1995 at the Consultative Group on International Agricultural Research (CGIAR) Secretariat in Washington, DC. Participants from six CGIAR centers and 17 outside organizations reviewed the current and proposed uses of remote sensing technologies, GIS, and digitized databases by the centers. The Workshop emphasized applications to forestry and agro-forestry.

The Workshop has links to the 1992 Global Resource Information Database (GRID)-Arendal I workshop conducted in Arendal, Norway and the GRID-Arendal II workshop in May 1995. The continuing development of United Nations Environment Programme (UNEP) activities through GRID-Arendal and other agencies helps to foster the collection and dissemination of natural resource, ecology, environment and socioeconomic datasets. GRID, located in Nairobi, Kenya is designated as the host organization and network server. Its interests also include such technologies as remote sensing and GIS.

Each CGIAR center outlined its current remote sensing and GIS programs. Discussions turned quickly to technical issues common to all the centers. On the second day, 13 of the outside agencies made presentations directed, in part, to assisting the centers meet goals and objectives. The presentations emphasized methodologies developed by the various agencies to study topics such as soils distribution and tropical deforestation, the collection and availability of digitized databases, and the assembly and access to metadata sets.

Final discussions resulted in naming three categories of CGIAR system needs, which should be presented for action and project financing at the GRID-Arendal II workshop. They include:

*defining CGIAR dataset and remote sensing requirements that are available from outside agencies,

*capacity-building requirements in GIS modeling and analysis within the CGIAR system, and

*linking the CGIAR centers to each other as well to other data and remote sensing institutions, including the UNEP/GRID network , the Consortium for International arth Science Information Network, and the World Conservation Monitoring Centre.

INTRODUCTION

The Workshop was held March 14-17, 1995 at the CGIAR headquarters in the World Bank, Washington, DC under USAID and CGIAR sponsorship. The core objective was to determine how to make optimal use of available digital data, GIS, and remote sensing to underpin the forest and agro-forest related research programs of the CGIAR.

All participants were remote-sensing and GIS practitioners, enthusiastic over the opportunity to

discuss mutual problems and viable solutions. They recognized that remote sensing and GIS applications are the primary practical means available to address issues that cover large geographic areas and are spatially interrelated. GIS was cited as an excellent tool because it employs a multidisciplinary approach, ensures coherence in systems strategies, involves partners systematically, and provides a common meeting ground for the natural and social sciences.

PARTICIPATING ORGANIZATIONS

CGIAR Centers

Two centers the International Centre for Research in Agroforestry (ICRAF) in Nairobi, Kenya and the Center for International Forestry Research (CIFOR) in Bogor, Indonesia are most directly involved with the forestry component of this topic. Given the broad applications of the technology, however, invitations to participate were extended to other CGIAR centers. Representatives from Centro Internacional de Agricultura Tropical (CIAT), International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), International Food Policy Research Institute (IFPRI), and International Institute of Tropical Agriculture (IITA) also attended. (See Annex A for a complete list.)

Prior to the Workshop, centers were requested to furnish a brief report covering (1) main areas of research being implemented that could most benefit from remote sensing and digital database inputs, (2) specific listings of digital database information most pertinent to ongoing and planned research, (3) principal current sources of such data already being used, (4) costs of data acquisition and possible cost reductions, and (5) inter-center collaborative mechanisms. Reports were received and distributed (see Annex B).

OUTSIDE ORGANIZATIONS

Many outside agencies participated in he Workshop; all have direct interests in remote sensing and GIS applications. They included representatives from USAID; GRID-Arendal; UNEP-GRID; United Nations Environment Programme (UNEP); World Conservation Monitoring Centre (WCMC); World Bank Environment Department and Office of Environmentally Sustainable Development (ESDAR); NASA s Pathfinder Project (Goddard Space Center and University of Maryland); U.S. Department of Agriculture s Forest Service, Agricultural Research Service-Natural Resources Institute, Soil Conservation Service, and Foreign Agriculture Service-Remote Sensing Program; Commission of the European Communities, Institute for Remote Sensing Applications TREES project; Texas A & M University; Blackland Research Center; The Nature Conservancy; Environmental and Natural Resource Information Center (ENRIC); the Consortium for International Earth Science Information Network (CIESIN); and Commonwealth Scientific and Industrial Research Organisation (CSIRO), Division of Forestry (Canberra, Australia).

DOCUMENTS

The principal Workshop document, A Source Book on Tropical Forest Mapping and Monitoring Through Satellite Imagery: The Status of Current International Efforts, was prepared by USAID's Environment and Natural Resources Information Center (ENRIC). Most of the participating agencies also contributed documents on remote sensing, GIS, and database applications (see Annex B).

WORKSHOP ORGANIZATION

To encourage interaction among attendees, Workshop leaders assigned participants to one of two groups. Outside participants were considered "producers" and CGIAR representatives, "users." On the first day, the users expressed a variety of concerns. This, in turn, enabled producers to gear their technical comments directly to the needs of the users.

The agenda was divided intothree sections. On the first day, CGIAR center users detailed their applications and needs for remote sensing, GIS, and databases. On the second day, outside producer agencies made their presentations. Third, a portion of the first two days and most of the last day featured open discussions meant to arrive at set of conclusions for the CGIAR centers, namely, "What do we do and where do we go from here?"

As the agenda developed, much new information on existing and major databases was presented by outside participants, and arrangements were made by center representatives to secure these datasets. As common requirements of the centers came to the fore, the need for networking emerged as an important topic, and new technical contacts were made among the participants.

BACKGROUND

The Workshop bridged the GRID-Arendal meetings (the first held in 1992 and the second scheduled for May 1995) and provided and important link between GRID-Arendal and UNEP. The two GRID-Adrenal meetings arose from discussions and a workshop in 1991 organized by several international organizations and the International Agricultural Research Centers (IARC) resulting in the formation of an ad hoc committee; both UNEP and CGIAR s Technical Advisory Committee (TAC) were included. That workshop recommended that the organizations should "work together to ensure [that] environmental data and data management technology are being generated and used in a coordinated fashion throughout the CGIAR system."

As a result, a UNEP-GRID consultancy was formed to report on the current state of GIS usage in the IARCs and to make recommendations for future collaborative efforts, particularly in relation to UNEP=s GRID system. The recommendation was made that "funding be sought for a technical meeting to consolidate the defiitions of the common databases required, identify which exist and how they may be obtained, and propose how those not yet available be compiled." This was done and the technical meeting, GRID-Arendal I, was held in September 1992.
The GRID-Arendal I meeting included sessions on five data themes database layers, climate data,

soil and terrain data, socioeconomic data, and production systems. The expert presentations are thoroughly covered in the final report (see Annex B). Recommendations were directed to implementing projects that had been identified and to finding additional resources to maintain the momentum produced by GRID-Arendal I.

Funding was then secured from the government of Norway through a UNEP Trust Fund, and matching funds were pledged by the World Bank. This has led to the GRID-Arendal II meeting, scheduled for May 1995, which aims "to establish long-term cooperative links between UNEP and the CGIAR, particularly in the use of the GRID and CGIAR networks to compile, distribute and maintain high quality natural resource and socio-economic digital datasets and to assist CGIAR centers ensure [that] capacity is in place to use such datasets in agricultural research activities." This effort is considered in keeping with the progress of the CGIAR centers between meetings with respect to "datasets in use, the technology in place, and existing institutional capacity."

LINK TO GRID-ADRENAL II

The USAID CGIAR Workshop helped to clarify technical requirements for further elaboration at GRID-Arendal II. Many of these are readily convertible into specific actions and projects. Others comprise coordination tasks to be implemented between and among CGIAR centers and with other agencies, including GRID-Arendal, UNEP, and the World Bank.

From the perspective of the participating CGIAR centers, the Workshop was oriented toward defining problems and solutions, networking, and establishing a frame of reference. Little time was spent describing the agency-specific projects that employ remote sensing, GIS, and databases. Instead, attention focused on changing technical parameters, remote sensing, GIS and database limitations and common problem areas in the use of current technologies. This led to discussions for future planning. Participants found that many problem areas could be remedied by using techniques, databases, satellite images and GIS applications that were presented by the outside participating agencies. Numerous interagency exchanges took place at this level, and a report on resulting arrangements has been requested from each agency.

WORKSHOP--- SUBSTANTIVE ISSUES

CHANGING PARAMETERS

Changes in computer hardware and software, along with cumulative progress in the compilation of databases, continue to progress at a rapid rate. Consequently, systems for processing and producing remote sensing/GIS products are also evolving rapidly. "In two years, (for example), we will have remote sensing spatial resolution at 1 or 4 meters, providing 50 to100 times more data than is currently the case." An increased Global Positioning System (GPS) is needed to interpret remotely sensed data at a higher resolution. Further, "GPS accuracy will soon be within one meter." Systems will thus require continual reconfiguring, and allowances must be made for increasing costs of hardware and software, for storage and maintenance, and for upgrading

database management systems. A possible solution to challenges posed by this trend could be to establish a CGIAR centralized unit to pursue these developments and advise other centers or to create such a role at GRID-Arendal, GRID, or UNEP. Thus, to avoid a "herding cats" situation, an established central focal point would link together interests of te numerous CGIAR and United Nations (UN) participating agencies.

SYNOPSIS OF TECHNICAL ISSUES AND SUGGESTED SOLUTIONS

SCALE OF SPATIAL RESOLUTION

The need is apparent to work both at increasingly larger scales of spatial resolution as well as downscaling from national and regional levels to individual watersheds. In addition, there is the further need for corresponding slope and elevation data. The 1:1 million scale, digital chart of the world (DCW), now supported by GIS, is inadequate for most projects. A determination must be made at what scale GIS research will be focused, and, therefore, what scale would be needed for data?

For example, research requires high-resolution information because problems typically under investigation are at the farm, field, or micro-catchment level. Ecological-oriented investigations (such as forestry and agroforestry in particular, and ecoregions "philosophically"), however, need to vertically integrate data with macro and regional scale data.

Because centers often need similar data, determining appropriate scales for the specific data types might be useful and would facilitate compatibility.

From one participant came the suggestion: "A partial resolution is to work closely with nationals who will demand a more localized approach," (hence, larger scale). This implies that the CGIAR centers should train nationals in GIS/remote sensing techniques who, in turn, "will be glad to develop (and make available) localized, large-scale databases." But another participant noted that "the CGIAR should not get involved in the training of remote sensing techniques and should only advise on training in GIS."

NEED FOR SYSTEM-WIDE COORDINATION

CGIAR centers must reach common agreement on a series of technical/communications issues, including the intended map/remote sensing scale. They must also help bring agronomists together with GIS people and agree on communications procedures among the centers.

TOPOGRAPHIC DATA ARE HIGH PRIORITY

A major priority is acquiring digital elevation model (DEM) data. The option is to continue at great expense to digitize existing topographic maps. Even with six full-time digitizers working in one institution to cover tropical America, Centro Internacional de Agricultura Tropical (CIAT), many years work lie ahead.

Acquiring the topographic information is fundamental. To integrate data layers via GIS, elevation and slope data (at appropriate scales) must accompany forestry, agriculture, watershed level, ecological, and other analyses. One solution rests in the knowledge that digital terrain model (DTM) information does exist at the U.S. Defense Mapping Agency (DMA). Much of the world is covered by 3-arc-second data, providing contour intervals at roughly 100-meter intervals. While DMA is now releasing a subset of 30-arc-second data, the 3-arc-second data are more appropriate to CGIAR center needs. Many U.S. and international organization agencies have individually and collectively approached DMA to secure release of the 3-arc-second data, and DMA now seems to be cooperating.

DATA RESCUE ISSUES

Costs are incurred in scanning and digitizing maps. Problems include determining which maps exist, the cost of purchasing maps, and digitizing expenses. "There is an enormous amount of existing apping that needs to be digitized." "There are very good map collections in the U.S. and at FAO, etc., that need to be scanned." A commonly shared GIS scanning and processing facility would yield significant cost reductions. Purchases of full-color digitizers and printers for use of CGIAR centers must also be considered.

DATA INVENTORY AND ACCESS

A constant problem exists in learning which digitized datasets (maps and statistics) are available. The CGAIR should inventory its holdings and, via partnerships (such as with UNEP), update, publish, and disseminate these data, using the Internet when possible. Efforts should be made to access inventories of "military" map holdings, along with those of FAO, U.S. agencies, and others.

MAP COMPILATION PRIOR TO DIGITIZING

"Enormous difficulties are encountered in compiling maps that are subsequently digitized." An attempt is being made by CIAT to query 5,000 to 6,000 experts by mail in order to derive a map of overall land use patterns for the subtropical and tropical America. A how-to manual for use in other regions of the world should result from the effort.

REMOTE SENSING

Physically acquiring remote sensing/satellite images poses a problem. "When satellite images need to be purchased and are not available from EOSAT, considerable time and effort is expended getting them from local ground receiving stations in Latin America."

SECURING FULLY RECTIFIED SATELLITE IMAGERY

Securing processed (fully rectified) satellite imagery is a problem, as is being experienced with the Pathfinder project. "The processing time at the EROS Data Center is a bottleneck." Alternatively, having to work with "raw" imagery (non-rectified) creates its own problems.

SOCIOECONOMIC DATSETS

Acquiring socioeconomic datasets is increasingly declared to be a priority at natural resources and environmental conferences and workshops. Yet, little is subsequently accomplished after these general statements of principle are recited. Meanwhile, geo-referenced socioeconomic databases are beginning to appear at the national and subnational levels. Practical steps can be taken to acquire and maintain them.

PRIORITIZING NEEDS

"There are prioritized needs for remote sensing acquisition and GIS applications. Finding corresponding additional resources is a vital need." GRID-Arendal II is designed to speak to these resource concerns.

OWNERSHIP AND DISTRIBUTION

The issue of ownership and distribution rights to purchased data and imagery needs more attention. "There is a question of legality [for example] once data sharing is conducted on CGIAR-wide basis." The problem results, in part, because datasets have become a revenue source for many countries so that use and distribution restrictions apply.

The above list of issues was discussed with the idea of establishing a cost-effective outreach program. Part of the program would be to establish a single institution to seve as a focal point to assist the entire CGIAR network. This institution would report on such issues as spatial resolution developments in remote sensing, digital terrain model availability, and practical means of accessing data. This institution would also develop a technical capacity to conduct a continuous map inventory, digitize databases, and provide scanning, distribution, and production services. UNEP was suggested as a potential candidate for this role ("UNEP as an integrating center"). Another possibility was to incorporate these functions in one of the CGIAR centers and designate one or two staff as "roving technical ambassadors" who can move between centers, ensuring efficiency in the sharing of data and models.

REMOTE SENSING AND GROUND TRUTHING

Linking ground truthing to remote sensing analysis is a major issue. The need for more and more ground truthing has increased as remote sensing applications develop, greater spatial resolution becomes available, and finer mesh spatial interrelationships are sought. And, as noted earlier, an increased GPS capacity is needed to interpret remotely sensed data at a higher resolution. The ground truth component was cited as critical. "Remote sensing and GIS, however, have outstripped the capacity to ground truth . . . and . . . there are obvious difficulties of matching ground attributes to remote sensing data."

LARGER BUDGETS FOR MAPS

Larger budgets are needed topurchase maps. Agencies often overlook the importance of map purchases. Digitizing costs must also be recognized.

RELATIONSHIPS TO NATIONAL PROGRAMS

Attention should be directed to transferring GIS techniques to national-level programs. This implies setting up training programs at the CGIAR centers. "The [International Institute of Tropical Agriculture, Ibandan, Niberia] experience has been positive to date, but funding for continuing development has run out." Results would include both increased acceptance of remote sensing and GIS applications at the national level as well as further national access to large-scale databases.

INSTITUTIONAL SUPPORT

Because of conflicting views over the value and role of remote sensing, GIS, and database acquisition, these technologies elicit mixed support in the CGIAR centers. For example, remote sensing and GIS applications are cutting-edge technologies that threaten to alter traditional decision making avenues and thus affect institutional power structures. Remote sensing and GIS products make decision making transparent and accessible and this can be disruptive. The technology also demands large budgets for maintenance, database acquisition, and for upgrading hardware and software. Thus, institutional competition arises over limited funds. One solution could be to promote separate or externally-funded supplemental budgets for these activities.

The need to gain support within and outside the CGIAR centers for the utility and importance of remote sensing, GIS, and database development was discussed. A definite problem exists in "putting GIS in a context people can understand (UNEP)." Some discussion comments were:
* "There is a need for an impact assessmnt look a context for the justification for use of GIS."

* "Having these rallying points is critical. These systems are so complex it will take all of us to develop a common ground for public acceptance."

* "The commercial types see it [remote sensing/GIS] for its dollar value and run with it. We see it

as science, which lessens our publicity of it."

Response: "Then sell it to your fellow scientists."

Response: "There is great opposition."

* "Put your constituents first. In forest ecosystem management, we are looking at holistic models, while they are looking at functional linkages. This [inter-disciplinary communications] is now a major constraint. However, GIS here is a powerful tool and in integrated and interactive fashion can help to overcome opposition."

Three suggestions emerged from this particular discussion: (1) to push at the national level to demonstrate the utility of remote sensing and GIS applications, leading to local databases "suddenly" becoming available. This implies promoting national level training courses in the use of the technology (mentioned earlier); (2) to prepare for distribution anecdotal materials on actual uses and practical applications of the technology; and (3) to prepare for publication a four-page brochure outlining and carefully explaining the steps involved in one or more remote sensing and GIS-based applications and highlighting the practical end use of the exercise.

PRESENTATIONS BY >PRODUCING@ AGENCIES

Thirteen outside agencies made presentations. These are summarized below (* = citation listed in Annex B).

Consortium for Earth Science Information Network (CIESIN): TERRA*

Brenda Faber provided a presentation on the Active Response GIS (AR/GIS). This interactive, computer-based tool supports land allocation discussions and negotiations among competing interests as they happen. Scenarios are collected/combined, implications modeled and discussed, and decision rationale for final recommendations are recorded automatically and linked to the original geographic databases. A separate presentation was made at the CIESIN office in Washington office by Robert Coullahan and Susan Schram on AR/GIS overall structure and objectives. Gateway, a powerful Internet query-and-search tool, was also demonstrated. It provides access to a wide range of socioeconomic and natural resource data information.

NASA: Pathfinder Project

Bill Lawrence, Jim Tucker, and Chris Justice reviewed the Landsat satellite image-based project underway to determine forest/land cover and change (1970s 1980s 1990s) for three-quarters of the world s tropical forested area. The attempt is to produce sub-1.0 kilometer resolution composite images at a regional scale. The project is developing improved vegetation indices for tropical forest areas and is attempting to delineate forest margin shifts. Other analyses include carbon stocks and habitat fragmentation. Emphasis is on the fact that the classified land cover data and the images themselves will be available for the cost of reproduction. The Landsat satellite images for this major project (1,000 separate scenes x three differnt years) are being produced at the U.S. Geological Survey s EROS Data Center in Sioux Falls, SD.

The Nature Conservancy: Rapid Ecological Assessments*

As presented by Roger Sayre, these national-level assessments depend on local-level national teams for field work and checking, the interpretation of satellite imagery, and GIS applications. The objective is to characterize and map natural communities and modified vegetation types. David Olsen presented a draft of an ecoregion map classification for Latin America.

World Conservation Monitoring Centre (WCMC)*

Mark Collins discussed WCMC services in pursuit of its goal to make conservation information more readily available to improve natural resource management. This is a joint International Conservation Union, UNEP and World Wildlife Fund initiative. WCMC acts as a clearing house for their conservation related data, particularly that in digital map form. Included in WCMC activities are research and analysis and provision of information and technical services. Among the numerous WCMC products are: continent-level atlases with country-specific mapping and information on tropical forest location and status and the GIS-based Biodiversity Map Library. A demonstration of the latter on a Sun workstation was shown at the World Bank.

USDA Foreign Agriculture Service (FAS)*

Terry Taylor noted that the FAS program supports U.S. interests and predicts global production of major grains.. A global assessment of predicted crop yields is made monthly , especially for competitor and key importing countries. This is a potentially valuable source of crop geographic data, e.g., locating specific production areas. FAS employs a "convergence of evidence method" and is now heavily involved in the use of satellite imagery and GIS. FAS has a large staff, much digitized vegetation data and worldwide annual vegetation indexes which are available along with weather data. FAS is moving away from applying methods and databases for "internal use only" to providing support to international programs such as to the CGIAR centers.

Environment and Natural Resources Information Center (ENRIC)*

Peter Freeman noted ENRIC s role as an information center under contract to USAID and listed several recent publications, among them one that succinctly reviewed each major USAID project activity in the area of environment and natural resources. Another is the Source Book on Tropical Forest Mapping and Monitoring Through Satellite Imagery: The Status of Current International Efforts, which served as the key Workshop document.

Texas A & M University, Blackland Research Center*

Paul Dyke commented on the many models and methodologies developed by the center for resource assessments. Remote sensing, GIS, and other tools are designed to address watershed, forest and river systems issues, land use land cover, soils, climate, topography, and demographic issues as related to agriculture and natural resources. Many of the models have been developed in support of USAID and CGIAR center programs.

GRID-Arendal

Sven Tveitdal spoke about the short- and long-term needs of GRID-Arendal including start-up, methods and data, and the release of primary data. For the long term he referred to the priority to obtain for GIS applications socioeconomic databases relevant to agricultural research. Considerable attention was also paid to strengthening linkages and better coordinating activities among GRID-Arendal, cooperating U.N. agencies and the CGIAR centers.

United Nations Environmental Programme (UNEP)*

Barry Henricksen offered comments on the UNEP s role as the UN system-wide earth watch coordinator, which promotes capacity building, data management, and data harmonization and dissemination through GRID. The GRID-Arendal project outline from the UNEP was also circulated.

United Nations Environmental Programme-Global Resource Information Database (GRID, Sioux Falls, SD)

Ashbindu Singh commented on the recent availability of the 1980 1990 comparative analysis of tropical forest cover and change undertaken by FAO. Further, a 1.0 kilometer global land cover database is in the planning stage at the EROS data center; the U.S. Defense Mapping Agency (DMA) has completed a 30-arc-second digital terrain model for a large part of Asia; and that there is now global drainage basin coverage available from EROS.

USDA Natural Resources Conservation Service (NRC)*

Paul Reich discussed the development of a computer system the Biophysical Resource Appraisal Support System (BRASS) to be used for the maintenance and retrieval of data on global biophysical resources. The program now accesses a global climate database of over 27,000 stations, U.N. Food and Agriculture Organization (FAO) soil database of the world, and the NRC s soil pedon database. BRASS has a geographical GIS component and the capacity to analyze and process geographic data.

Commonwealth Scientific and Industrial Research Organization (CSIRO) Division of Forestry*

Trevor Booth discussed CSIRO climatic mapping programs that have been developed to identify areas suitable for growing particular species and provenances. The simulation mapping programs using a version of the Plantgro model include soil data as well as monthly mean values for maximum temperature, precipitation, evaporation and solar radiation.

Commission of the European Communities, Institute for Remote Sensing Applications: TREES

Jean-Paul Malingreau reviewed aspects of TREES, a project similar to NASA s Pathfinder in that one objective is to determine tropical forest cover and change. This project uses a wide range of

satellite imagery including System Pour l Observation de la Terre (SPOT) and radar imagery. TREES is based on global 1.0 kilometer Advanced Very High Resolution Radiometry (AVHRR) data and "ground truthing" using higher resolution SPOT imagery. The high resolution clearly shows forest margins, annual comparisons are being tried, as is a typology of spatial deforestation patterns (linear, diffuse, wishbone, etc.). Results are integrated with the Tropical Forest Information System (TFIS). Phase II, about to start, will extend TFIS and make products available through Internet/WorldWide Web.

CONCLUSIONS AND RECOMMENDATIONS

Participants agreed that the Workshop had been needed and was very beneficial. It established how far things had moved ahead since GRID-Arendal I in 1992, and it provided a frame of reference for GRID-Arendal II.

Final day workshop discussions (ranging from suggestions of very specific requirements in remote sensing and GIS common to the CGIAR system to proposals for declarations of broad-reaching research objectives and goals) led to three aeas of common need. These categories, requiring subsequent action, were accepted and registered as Workshop conclusions to be presented at GRID-Arendal II. The more specific recommendations of several participants wil be held for presentation at GRID-Arendal II in the context of the three categories:

1. Needs related to defining CGIAR dataset and remote sensing requirements from outside agencies.

2. Needs related to capacity-building requirements in GIS modeling and analysis within the CGIAR system.

3. The need to link the CGIAR centers together and as well to other data and remote sensing institutions, such as the UNEP/GRID network, Consortium for Earth Science Information Network (CIESIN), and World Conservation Monitoring Centre (WCMC).

With specific reference to the Center for International Forestry Research (CIFOR), Bangor, Indonesia and the International Center for Research in Agroforestry (ICRAF), Nairobi, Kenya, the forestry and agro-forestry institutions, the conclusions and recommendations are:

*The use of remote sensing in forestry and agro-forestry-related research is viable when the CGIAR s approach is to focus on a few "scenes" and develop detailed ground-truthing and related links to the ongoing micro-level research. The CGIAR can then contribute to partners (Pathfinder, TREES) who have mandates to build macro and regional scale databases from which CIFOR and ICRAF will build extrapolation domain.

Accordingly, the recommendation is for CGIAR to create formal agreements with partners working at macro/regional scales to freely share licensed remote sensing scenes.

*A second conclusion is that natural resource management (NRM) research requires high-

resolution data. NRM research also requires the integration of information from many disciplines. Use of GIS and spatial database management systems is thus required. The cost of high resolution information (from satellites to agronomic field trials to biodiversity counts and farmer resource issues) requires that the context of the benchmark site be carefully considered. The value in resolving NRM problems as manifested at the micro scale only comes when solutions apply over broad areas. Thus, the links to macro scale date typically derived from partner sources are vital.

The recommendation is that the investment in GIS hardware, software, and human resources should be carefully considered and regularly reviewed.

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